

Welch (W. H.) & Clement (A. W.)
With the Author's Compliments (A. W.)

Br41306

W

REMARKS ON

HOG CHOLERA AND SWINE PLAGUE.

BY

WILLIAM H. WELCH, M.D.,
PROFESSOR OF PATHOLOGY, JOHNS HOPKINS UNIVERSITY,

AND

A. W. CLEMENT, V.S.



[From the Pathological Laboratory of the Johns Hopkins University.]

From
Proceedings of the Thirtieth Annual Convention of the
United States Veterinary Medical Association and
First Veterinary Congress of America. Art Palace,
Chicago, October 16, 17, 18, 19, and 20, 1893.
Philadelphia; Printed for the Association, 1894.

REMARKS ON HOG CHOLERA AND SWINE PLAGUE.¹

BY WILLIAM H. WELCH, M.D.,
PROFESSOR OF PATHOLOGY, JOHNS HOPKINS UNIVERSITY,

AND

A. W. CLEMENT, V.S.

(From the Pathological Laboratory of the Johns Hopkins University.)

OUR observations of hog cholera and swine plague relate mostly to these diseases as they have occurred in Maryland, particularly in the vicinity of Baltimore, since the year 1887, although we have examined cases, specimens, and cultures, also, from various other parts of the country. Our work on this subject began soon after the publication of the discovery of the germs of hog cholera and of swine plague by Salmon and Theobald Smith, and has been carried on independently of that of the Bureau of Animal Industry. Although the publications of this Bureau have, to a large extent, anticipated the publication of our results, nevertheless the conclusions and the manner of their presentation by the Bureau of Animal Industry have been subjected to so much hostile criticism (most of it, in our opinion, uncalled for and unjust), and there has ensued so much confusion as to this whole subject, that it seems important to present additional and independent observations of these epizootic diseases of swine in this country.

Our results are in large measure confirmatory of those reached by the Washington Bureau. As will appear from this paper, there are, however, some points as to which we have arrived at different conclusions from those of the Bureau, and we believe that we have added some new facts of importance. We also claim to have placed upon a firmer basis, by the observance of stricter precautions in guarding against possible error, some of the conclusions reached by the Bureau upon what we regard as insufficient evidence.

Our studies have extended over several years, and have been made upon more than twenty herds of swine in different epizootics. On

¹ Read October 20, 1893, at the First International Veterinary Congress of America, held in Chicago, Ill., October 16th to 20th inclusive, 1893.



this occasion we propose to present the more important general results of our investigations, especially as to points which may be considered not wholly settled, and to leave the presentation of our protocols and the full details to a later monograph.

We have adopted the nomenclature of the Bureau of Animal Industry, and understand by the hog-cholera bacillus the micro-organism which was first clearly described by Theobald Smith, and which is called by this name in the various reports and publications of the Bureau since their third report for the year 1886 (published in 1887). By hog cholera we understand the disease in swine caused by this bacillus. We employ the name swine-plague bacillus for the micro-organism so designated in the reports of the Bureau of Animal Industry since that for 1886, and by swine plague we understand the disease caused by this bacillus.

The nomenclature of the epizootic diseases of swine has become so confusing that it is difficult for one not familiar with the various steps in the development of our knowledge of these diseases, and with the varying usage of different writers, to pick his way intelligently through the recent literature of this subject. In each country where hog cholera occurs different names are used for it. In England it is generally called swine fever, and by Klein, also, pneumo-enteritis of swine; in Denmark and Sweden, swine pest (*Svinpest*) and swine diphtheritis (*Svinediphteritis*), and in France, pneumo-enteritis of swine (*pneumo-entérite du porc*), and lately the American name, hog cholera, has also been used in France. Some confusion, particularly in the minds of some German writers, and excusably so, has resulted from the fact that the disease called hog cholera by the Bureau of Animal Industry and by veterinarians in this country, is called by F. Billings swine plague. In German writings the name swine plague seems to be more generally employed to designate the American hog cholera than is the latter name. We venture to suggest that if German writers in this respect would conform to American usage and use the name hog cholera when speaking of the American disease, some confusion would be avoided.

The affection called swine plague by the Bureau of Animal Industry since the report for 1886 (in the report for 1885 this name was given to hog cholera) and by us, was for a time not admitted to exist by F. Billings, and is now accepted by him only as a complication of hog cholera of relatively slight importance. Swine plague seems to be identical with the German *Schweine-seuche*, although we do not consider this identity, for reasons which will be stated later, as

settled beyond all doubt. It has been designated, also, infectious pneumonia of swine, and is regarded by the Bureau of Animal Industry as an infectious pneumo-enteritis. The disentanglement of the two diseases, hog cholera and swine plague and still more of the two micro-organisms, the hog-cholera bacillus and the swine-plague bacillus, as regards their relations to each other and to the bacteria isolated from swine epizootics in Europe, and even as to their relation to swine diseases in this country, has been rendered difficult partly in consequence of difficulties inherent in the bacteriological study of these diseases, but largely from imperfections in these bacteriological studies, both in this country and in Europe, and also from ill-considered and confusing writings by more than one contributor to the literature of these subjects.

We do not consider that the names hog cholera and swine plague are either of them particularly fortunate designations, but usage controls nomenclature in medicine as well as in ordinary speech, and we believe that it would add still more to existing confusion were we to invent or adopt other names which are little likely to supplant those in ordinary use. Some consensus of opinion is requisite in securing the employment of new terms. We beg to suggest that an authoritative expression of opinion by the United States Veterinary Association as to the best nomenclature of the epizootic diseases of swine would be useful, especially if in this matter the Association would act in co-operation with foreign societies and authorities, so as to secure a greater degree of uniformity in international usage. Our understanding of these diseases is now sufficiently complete to justify such an undertaking.

We shall give, in the first place, a brief summary of the more important lesions of hog cholera which we have observed. The possible anatomical lesions of hog cholera are so manifold that a large experience is necessary to render one practically familiar with all of them. Of these lesions, the so-called "buttons" in the intestine are unquestionably the most characteristic. These buttons are elevated, circumscribed, round or oval areas of necrotic inflammation, of firm consistence, of yellow, yellowish-black, or black color, often presenting an appearance of concentric rings, and involving the mucous and submucous coats, and sometimes all of the coats of the intestine. They are sufficiently familiar to the members of this Association.

Scarcely less common, but much less characteristic, than the buttons are diffuse and circumscribed superficial necroses and diffuse and circumscribed diphtheritic inflammation of the intestinal mucosa.

Ulcers, hemorrhages, hyperæmia, follicular swellings, and catarrhal inflammation of the intestine are common. The intestinal lesions affect especially the large intestine, being often, although not invariably, most intense near the ileo-cæcal valve. They may be limited to the large intestine, but it is not rare for the small intestine and stomach to be similarly affected.

Necrotic areas similar to those called "buttons" may occur in various parts of the body besides the intestine and stomach. We have observed them repeatedly on the pharynx, the tonsils, tongue, gums, lips, other parts of the buccal mucosa, the nasal mucous membrane, conjunctivæ, gall-bladder and bile ducts (where, indeed, they are common), præputial sac, vagina, and on various parts of the integument. They are characterized by essentially similar histological appearances in all of these situations—an exudate of fibrin and leucocytes, proliferation of the fixed cells, capillary thrombosis in an early stage, followed by speedy coagulative necrosis, with much nuclear fragmentation of the exudative and tissue cells.

Redness of the skin, particularly of the belly, inside of the thighs, and about the ears, is common, but not constant.

Swelling of lymphatic glands, especially of the inguinal, mesenteric, retro-peritoneal, and bronchial, sometimes of all of the lymphatic glands of the body, is common in acute cases, but not constant. This swelling is often accompanied by hemorrhages into the glands and foci of necrosis, sometimes visible to the naked eye, sometimes revealed only by the microscope, these changes giving a variegated, mottled appearance to the glands.

Small yellowish, or yellowish-white, or reddish foci of necrosis are common in the liver, both macroscopic and microscopic.

The condition of the spleen is variable; it may be unaffected or swollen, firm or soft, and contain fibrinous thrombi or, rarely, infarcts or hemorrhages.

An interesting change, hitherto overlooked, is the occasional occurrence of hyaline thrombosis of the renal capillaries, both glomerular and intertubular. When this condition is well marked, there are albuminuria and even anuria, and it is impossible to force more than a minimal quantity of injecting fluid into the renal vessels. The hyaline stains like fibrin with Weigert's fibrin stain, and is evidently closely allied to fibrin. Sections of such a kidney, stained with Weigert's fibrin stain, look almost as if the bloodvessels had been injected artificially with Berlin blue. This thrombosis may be associated with little alteration of the tubular epithelium, or with or with-

out the thrombosis there may be fatty degeneration of the epithelium, genuine diffuse nephritis, and hemorrhages in the kidney.

Pyelitis, usually hemorrhagic in character, and hemorrhages into the mucous membrane of the bladder, we have repeatedly observed. Blood-clots may be found in the renal pelvis. General fibrinous pleurisy may occur. Diffuse peritonitis we have observed only in hog cholera complicated by the presence of other bacteria.

It is the opinion of the Bureau of Animal Industry that pneumonia is not a lesion which belongs to uncomplicated hog cholera, although some broncho-pneumonia is admitted to be sometimes present. Various types of pneumonia are found in many pigs dead of hog cholera. In the great majority of our cases strongyles were present in the bronchi, and foci of broncho-pneumonia could often be referred to their presence. There were, however, observed in many cases larger or smaller areas of hepatization, often partly necrotic, and of types which cannot be referred to the presence of strongyles. In a large proportion of these cases the swine-plague bacillus was present, with or without coincidence of the hog-cholera bacillus, in the lungs, and as the swine-plague bacillus can be shown experimentally to be capable of producing pneumonia, these cases cannot be adduced in support of the view that the hog-cholera bacillus alone may cause pneumonia. We have, however, observed some cases of pneumonia not referable to strongyles, in which the hog-cholera bacillus was present alone in the lungs, and as we possess experimental evidence, as will be explained later, that the hog-cholera bacillus may produce pneumonia in swine, we are of the opinion that pneumonia may be a lesion of uncomplicated hog cholera. This pneumonia may be associated with fibrinous pleurisy, also referable to the hog-cholera bacillus.

Fatty degeneration of the heart may occur in hog cholera. Acute and chronic endocarditis and myocarditis are rare lesions which we have observed.

In not a few acute, and in some chronic cases, ecchymoses are so numerous in the skin, mucous and serous membranes, and in the viscera, that a hemorrhagic type of the disease may properly be distinguished. Even diffuse hemorrhages may occur, particularly in the connective tissue around the kidney. Acute cases may occur of a septicæmic type without intestinal lesions.

Although a distinction between acute and chronic hog cholera is in many cases useful and appropriate, there are so many transitional types of the disease that it should be understood that there are no sharp dividing lines between acute and chronic cases.

We have had opportunity to study the process of repair of the intestinal lesions in pigs which have partly or wholly recovered from natural and experimental hog cholera, but we shall not take this opportunity to describe these interesting reparative changes.

The greater our experience in the bacteriological study of hog cholera became, the more convinced were we of the importance of completeness in the bacteriological examination of each case. To obtain thoroughly trustworthy and satisfactory results we consider it important in each case to make cover-slip preparations and cultures from the various organs of the body, especially from the lungs, spleen, heart's blood, kidney, liver, lymphatic glands (particularly the mesenteric), intestinal lesions and inflammatory exudates elsewhere if present, and also to inoculate mice or rabbits with bits of these organs and lesions. Such an examination takes much time, but a few cases carefully studied in this thorough manner are worth more than many cases imperfectly studied.

Without such complete examination it will often happen that one cannot be sure that other micro-organisms, particularly the swine-plague bacillus, were not present in some of the internal viscera, together with the hog-cholera bacillus. The hog-cholera bacillus may be present in such small number and so limited in distribution that it is likely to be overlooked unless all of the parts named are examined both by cultures and by inoculation of animals. It is often necessary to inoculate the culture tubes with tolerably large fragments of the spleen and other parts in order to detect the presence of hog-cholera bacilli, so few may these be. The colonies of the hog-cholera bacillus are generally distinguishable from those of the swine-plague bacillus by their larger size and coarser, more opaque, grayish-white growth; but sometimes, especially in roll and plate cultures crowded with colonies, these differences are so little marked and each of these varieties of colony is in itself so little characteristic that it is particularly important to secure the aid of inoculation of animals with parts of organs to differentiate these organisms and to recognize the presence of one or both. If both swine-plague bacilli and hog-cholera bacilli are present in the part examined, rabbits and mice inoculated with this part will die of swine plague, and if reliance were placed solely upon the animal experiment the hog-cholera bacillus, if present, would be overlooked.

The statement is made in publications of the Bureau of Animal Industry, that if the hog-cholera bacillus is present, it will be found

invariably in the spleen.¹ In the cases in which we have demonstrated the presence of the hog-cholera bacillus we have very rarely failed to find it in the spleen. Still we have notes of a few cases in which both the inoculation of animals and of culture media with good-sized bits of the spleen has yielded negative results, and the hog-cholera bacillus has been found in other parts, so that we must dissent from this statement. We have found the hog-cholera bacillus in the intestine when it has been absent from the spleen.

When a mixture of pathogenic organisms has been present we have been helped out occasionally, especially in examining the intestine, by making roll or plate cultures from the neighborhood of the seat of inoculation in rabbits. By this means we have detected both the swine-plague bacillus and the hog-cholera bacillus together in the intestine, when otherwise we should have failed to find the latter organism.

One of us (Welch) has described in an article published in 1889² the principal characters of the hog-cholera bacillus and of the swine-plague bacillus, and it is not necessary to repeat here this description, which was essentially confirmatory of the results obtained in the Bureau of Animal Industry.

We wish, however, in this connection, to express our conviction that the organism described by Selander in 1890, and probably also that by Metchnikoff later, as the hog-cholera (or swine-pest) bacillus is not identical with the genuine hog-cholera bacillus as we know it in this country. This point needs especial emphasis, as the Metchnikoff hog-cholera bacillus seems to have been accepted without question as the genuine hog-cholera bacillus, and the already existing great confusion as regards this organism is likely to become almost inextricable unless this error be corrected.

Our present criticism refers only to the organism described by

¹ Theobald Smith: "Special Report on the Cause and Prevention of Swine Plague," pp. 44, 103, Washington, 1891, and other places. It should be said, however, that Dr. Smith admits the possibility of the localization of the hog-cholera bacillus in the intestine, when it is absent from internal organs, but he has not published observations demonstrating this fact. He says, *op. cit.*, p. 103: "The difficulty of examining the intestines for pathogenic bacteria and the amount of labor involved is very great, and hence for want of time and sufficient assistance this part of the work has been set aside in these investigations, and the attention centred on the lungs and other internal organs." Notwithstanding this admission, we do not think that he always recognizes sufficiently in his publications the possibility that some of the cases with intestinal lesions which he regards as pure swine plague may have been combined swine plague and hog cholera, with localization of the hog-cholera bacilli in the intestine, nor does he appear to know that rarely hog-cholera bacilli may not be found in the spleen, even when demonstrable in other internal organs.

² William H. Welch: "Preliminary Report of Investigations Concerning the Causation of Hog Cholera," *The Johns Hopkins Hospital Bulletin*, December, 1889.

Selander in 1890, in the *Annales de l'Institut Pasteur*, and not to that described by him as the bacterium of swine pest in the *Centralblatt für Bakteriologie* in 1888. By experiments conducted in Pasteur's laboratory under Roux, Selander, starting with a culture of the swine-pest bacillus of 1888, which killed rabbits in three to seven days, claimed by a special procedure to enhance the virulence of this bacillus to a point at which it killed pigeons, which are not very susceptible to the hog-cholera bacillus, in ten to twelve hours, and rabbits in twelve to fifteen hours by subcutaneous injection of small doses, and in five hours by intra-venous injection. The procedure consisted essentially in inoculating in series rabbits with the crushed spleens in bouillon of rabbits dead of inoculation with the bacillus, the spleen of one rabbit being used to inoculate the next, and so on. He found that the fourth rabbit in this series died in fourteen hours. The virulence was still further enhanced by inoculating pigeons in series.

Selander's statements were so much at variance with our experience that we have repeated his experiments exactly according to his directions. We have carried the series to over twenty rabbits without obtaining any noticeable diminution in the duration of life of the inoculated rabbits. At the end, as well as at the beginning, of the series the rabbits died in four to six days after inoculation.

The hog-cholera bacillus is most tenacious of its special characters. Original variations in virulence, and to some extent in other properties, occur, but with one and the same bacillus we have not succeeded by successive inoculation of animals in producing very marked changes in the degree of virulence, nor have we ever met a kind of hog-cholera bacillus which, by subcutaneous inoculation of ordinary doses, regularly killed rabbits in less than three days, although occasionally rabbits may die in less than that time.

Dr. Selander, through the friendly mediation of Prof. Salomonsen, of Copenhagen, kindly supplied one of us (Welch) in August, 1890, with a sealed tube of the blood of a pigeon dead of inoculation with his bacillus, and also with an hermetically sealed agar culture of the same bacillus of exalted virulence. We beg to express our thanks to both Dr. Selander and Prof. Salomonsen. These tubes

¹ One of these tubes was dated either April 28, 1890, or July 28, 1890; we could not positively make out which. Assuming that it was the earlier date, the culture, when examined, would have been less than six months old. The other tube was undated. As the dates of Selander's experiments in Pasteur's Institute, as given in his article, run from March to June, 1890, the cultures could hardly have been at the utmost more than seven or eight months old, and were probably, as appears from the date mentioned above, less than that age.

were received in Berlin, and were brought to this country by one of us in the same package with cultures of *Schweine-seuche*, swine-pest, swine-fever, and other bacteria. They were opened and examined early in October.

Selander's tubes contained a short, oval bacillus, resembling the bacteria of the hemorrhagic septicæmia group. The organisms in both tubes were dead, neither cultures therefrom nor inoculation of rabbits or mice yielding positive results. The cultures of various other organisms conveyed in the same package from Berlin were all alive. The media in Selander's tubes were not at all dried down. Unless some unknown injurious agency acted upon these cultures of Selander's bacillus before they were handed to us by Prof. Salomonsen, the fact that the cultures were dead excludes, we believe, the presence in them of the hog-cholera bacillus, which survives at least two years in agar culture protected from desiccation. Selander, however, believes that his bacillus with exalted virulence has become less resistant than the hog-cholera bacillus of ordinary virulence; but in view of our experience in repeating Selander's experiments to heighten virulence, we believe that the bacillus which he obtained after serial inoculations of rabbits and pigeons was not derived from the hog-cholera (swine-pest) bacillus, but was some different species of micro-organism.

We should suspect that possibly in the course of his experiments there developed a case of rabbit septicæmia, and that the subsequent work was done with a culture from such a source, were it not for his statement that the subcutaneous, intra-venous, or alimentary inoculation of swine with his bacillus with heightened virulence produced diphtheritic enteritis, a lesion which is not known to be caused in swine by the bacillus of rabbit septicæmia. Microscopically, the bacteria in Selander's cultures given us were decidedly smaller than the hog-cholera bacillus. Many bacilli of the hemorrhagic septicæmia group die in a few days or weeks in artificial culture. In fact, we have had some difficulty in obtaining from Europe living cultures of the *Schweine-seuche* bacillus which belongs to this group. Whatever this organism of Selander may have been, we feel convinced that it was not our hog-cholera bacillus, and we base this conclusion upon the results of his experiments in Pasteur's Institute, as published, and upon our experience with the cultures with which he kindly supplied us.

We are unable, moreover, to reconcile with the properties of the genuine hog-cholera bacillus the description given by Metchnikoff of

the so-called microbe of hog cholera with which he performed his experiments on immunity, described in the *Annales de l'Institut Pasteur*, May, 1892. He says that he has obtained the same results as those of Selander. He describes his hog-cholera microbe as most pronouncedly pleomorphic, growing in short rods, long threads, and veritable cocci, sometimes as a streptococcus and killing rabbits in a few hours. He gives it the name *cocco-bacillus suinum*. This name and this description are singularly inappropriate for the genuine hog-cholera bacillus, which is no more pleomorphic than the typhoid bacillus. Unlike the swine-plague bacillus, it does not grow in forms suggesting cocci. Metchnikoff states that the blood-serum of the rabbit is not germicidal for his hog-cholera microbe. In our experience the normal rabbit's serum is germicidal for the hog-cholera bacillus to about the same extent that it is for the typhoid bacillus. We believe Metchnikoff's hog-cholera microbe to be one of the hemorrhagic septicæmia bacilli, possibly the swine-plague or Schweine-seuche bacillus.

In many German publications the hog-cholera bacillus is placed under the group of bacteria belonging to the so-called hemorrhagic septicæmias. Elaborate studies have been made in German laboratories, showing that the hog-cholera bacillus is not identical with the Schweine-seuche bacillus, which is a member of the hemorrhagic septicæmia group. There never was any good reason to suppose that it could be identical with the latter bacillus, and the amount of labor given to repeatedly demonstrating this evident fact, sufficiently familiar to us since 1888, has been a source of surprise to American investigators (with the possible exception of F. Billings) who were acquainted with the hog-cholera bacillus on the one hand and the various bacteria of the hemorrhagic septicæmic group on the other hand. We consider that the hog-cholera bacillus bears more resemblance to the typhoid and colon groups of bacteria (although nothing would be gained by classifying it with either group) than to the hemorrhagic septicæmia group, and that it is misleading to place it in the latter group, where the swine-plague bacillus, the Schweine-seuche bacillus, the Wild-seuche bacillus, etc., belong.

As regards the distribution and recognition of the hog-cholera bacillus in the natural disease in swine, there are certain points which we wish to emphasize. Although in ordinary cases of hog cholera there is no difficulty in recognizing the presence of the hog-cholera bacillus, cases occur in which the determination of the presence of this bacillus is difficult, and there are chronic cases with

typical lesions of hog cholera, and cases even with apparently fresh lesions, in which the most complete bacteriological examination fails to reveal the presence of this micro-organism.

In one of our cases we demonstrated hog-cholera bacilli in abundance in the intestine, which was the seat of rather superficial small buttons and of fresh diphtheritis, and found only a single colony of the hog-cholera bacillus in the roll culture from the liver, and a very few colonies in the culture from the peritoneum. Cultures inoculated with abundant material from the spleen, blood, lungs, and kidney contained no colonies of this bacillus, and a rabbit inoculated with the spleen survived. This case shows that the bacteriological examination of the intestine in hog cholera, difficult as it is, should not be neglected, and that without such examination the presence of hog-cholera bacilli may be overlooked. In several similar cases with intestinal lesions typical of hog cholera, swine-plague bacilli were present in the lungs and likewise sometimes in other parts. The danger of mistaking such cases for pure swine-plague infection, so far as can be determined by bacteriological examination, is apparent.

We have evidence that the hog-cholera bacillus may have entirely disappeared from the body, so far as can be determined by cultures and inoculation of animals from the various organs of the body, including the intestine, at a period when characteristic intestinal lesions are still present. This evidence rests upon the study of herds in which we have found pigs dead of hog cholera with hog-cholera bacilli, and later have examined, without finding these bacilli, pigs from the same herd, with similar intestinal lesions—some evidently undergoing repair, others still typical buttons.

Pigs in which the intestinal lesions of hog cholera persist after the disappearance of the hog-cholera bacilli may be infected also with swine plague. We interpret thus cases in which the most typical intestinal lesions of hog cholera—that is, perfectly characteristic buttons—are present, and still the bacteriological examination shows the presence of only swine-plague bacilli. We have observed whole herds in which the affection was of this character. These buttons we regard as characteristic of hog-cholera—as much so as typhoid ulcers are of typhoid fever. We possess convincing experimental proof that these buttons are caused by the hog-cholera bacillus, and there is no evidence that the swine-plague bacillus or any other species of micro-organism is capable of producing them.¹ In the present state of our

¹ An exception would be made to this statement if the recently published view of Bang were confirmed, that still a third bacterium, which he calls the necrosis bacillus, is concerned

knowledge we consider that whenever typical buttons are present the inference is justifiable that the hog-cholera bacillus has been active in the case, whether or not it be demonstrable at the time of autopsy. There is no difficulty in understanding how such necrotic lesions, when extensive, may lead to the death of the pig, even after the specific germ has died out. In most, but not all, of these fatal chronic cases with lesions characteristic of hog cholera, but without the hog-cholera bacillus, there is concurrent or secondary infection with another micro-organism, most frequently with the swine-plague bacillus, and the death of the animal may be attributed in part or wholly to this other infection.

Characteristic buttons are by no means present in all cases of hog cholera—not even in all chronic cases. We possess evidence similar to that already mentioned, based upon the examination of previous or concurrent cases of hog cholera in the herd, that pigs may die with forms of intestinal necrosis which cannot properly be called buttons, and even with simple intestinal diphtheritis after the hog-cholera bacilli have disappeared, or at least are no longer demonstrable by culture or inoculation of animals, although they had been demonstrated previously in cases with similar lesions in the same herd. Such observations with negative bacteriological results might be interpreted as opposed to the acceptance of the hog-cholera bacillus as the cause of hog cholera, were it not for the conclusive experimental demonstration of the causative rôle of this bacillus.

In view of the facts which have been mentioned, it is clear that great caution should be exercised in the interpretation of cases in which the bacteriological examination reveals only the swine-plague bacillus, although the intestinal lesions of hog cholera are present. Until there is experimental evidence that the swine-plague bacillus can produce such lesions, it is not warrantable to refer them to the presence of this organism.

In a number of cases we have isolated hog-cholera bacilli of varying degrees of attenuation of virulence. The attenuated form most frequently met is one which fails to kill rabbits by subcutaneous inoculation, but is fatal after intra-venous inoculation with the characteristic lesions produced by the virulent bacillus, but with a

in the natural disease designated hog cholera or swine pest. The deeper necroses, that is, the buttons, he attributes to the invasion of this necrosis bacillus after the way has been prepared for it by a superficial croupous inflammation set up by the hog-cholera bacillus. Our experiments, however, show that the hog-cholera bacillus may cause these buttons, and we cannot, therefore, accept with the present evidence a second micro-organism as the cause of such peculiar and typical lesions. We are acquainted with Bang's article only by the abstract in the *Centralblatt für Bakteriologie*, 1893, Bd. xiii. p. 203.

greater tendency by this method of inoculation to cause intestinal hemorrhages, necrosis, and diphtheritis in rabbits. Similar observations have been made by Theobald Smith. These intestinal lesions in rabbits and guinea-pigs are not, however, extremely infrequent after intra-venous, and they may occur after subcutaneous inoculation, and often after ingestion of virulent hog-cholera bacilli. We have also met bacilli with all essential morphological and cultural characters of the hog-cholera bacillus, but incapable of killing either rabbits or mice, at least in ordinary doses. We have succeeded in causing intestinal diphtheritis with necroses by feeding swine cultures of partly attenuated hog-cholera bacilli, although the pigs have usually recovered. These observations are of importance with reference to the question of identity of the hog-cholera bacillus and the swine-pest bacillus, as will be explained later.

As we have found in the same pig both virulent and attenuated hog-cholera bacilli, it is probable that the hog-cholera bacillus may suffer loss of virulence in the body of swine affected with hog cholera. It is not necessary to assume that the degree of virulence found at autopsy is identical with that possessed by the bacillus at the time of invasion of the animal.

In several instances the subcutaneous inoculation of rabbits with necrotic intestinal buttons has not proven fatal, even when the inoculation with the spleen and other organs of the same pig has caused fatal hog-cholera in rabbits. This would indicate that the hog-cholera bacilli were no longer present in the buttons, or, if present, were, in contrast with those in the spleen and other internal organs, so weakened in virulence as not to be fatal to rabbits by subcutaneous inoculation, or that the mixture with intestinal bacteria prevented the usual manifestation of their pathogenic activity. The last supposition we consider improbable, as often, indeed usually, the inoculation of rabbits with the fresh intestinal lesions of uncomplicated hog cholera causes death, with the usual lesions and presence of hog-cholera bacilli in the rabbit. In the combined infection with hog cholera and swine plague the inoculation of rabbits with pieces of the intestine is likely to produce swine plague.

In our experience there has been considerable similarity in the results of the bacteriological examination of the different pigs of the same herd, whether affected with pure hog cholera or with hog cholera combined with swine plague; but there are so many exceptions to this that it is hardly proper to set up any rule on this point.

Often in hog cholera there may be invasion of other bacteria than that mentioned. The most frequent of these secondary invaders (excluding the swine-plague bacillus) has been in our experience the bacillus coli communis, which may, without sufficiently careful examination, be mistaken for the hog-cholera bacillus, which morphologically, and even in many of its cultural properties, is not so unlike the colon bacillus. As has been shown by one of us (Welch¹), intestinal lesions such as those present in hog cholera favor the invasion into internal organs of the bacillus coli communis.

We will now consider briefly the experimental evidence that the hog-cholera bacillus is really the cause of hog-cholera. Although the bacteriological study of the natural disease speaks decidedly for the hog-cholera bacillus as the cause of the disease, there are such difficulties in this study, and so many complicating factors, that a reasonable skepticism is warranted until the conclusive experimental demonstration is brought that the hog-cholera bacillus, when inoculated in pure culture into healthy swine, is capable of reproducing the disease as it is observed under natural conditions. Above all, it should be demanded that the typical button-like lesions are reproduced. The production of simple intestinal diphtheritis, with which previous experimenters seem to have been content, is a lesion which may be caused experimentally in animals by various micro-organisms, as well as by irritant substances, and cannot be considered a satisfactory reproduction of the natural disease in its most characteristic feature, although it is true that the natural disease occurs with diffuse intestinal diphtheritis as the only intestinal lesion.

It is not clear to us that other investigators have succeeded under proper precautions in reproducing these buttons experimentally, and this gap in the experimental evidence we are able to fill.

We shall not discuss here our experiments upon rabbits, mice, guinea-pigs, and pigeons, interesting as are the lesions produced in these animals by the hog-cholera bacillus.

We have adopted every precaution to avoid error in the experiments on swine, and we consider that without such precaution experiments on swine with the hog-cholera bacillus in regions where the natural disease prevails are of little value. We have purchased the experimental pigs from places where disease was not present and had not been known to occur, and from persons who raised their own pigs, not purchasing from others. We soon found that the

¹ Welch: The Bacillus Coli Communis; "the Conditions of its Invasion of the Human Body and its Pathogenic Properties," The Medical News, December 12, 1891.

dangers of accidental infection with hog cholera in the Pathological Laboratory of the Johns Hopkins University, where we made autopsies on the natural disease, were such that we abandoned such experiments there, and erected pens or kept boxes in clean stables and other places where there was no possibility of infection of the locality, and we frequently shifted from place to place in making the series of experiments. Every precaution was taken to guard against accidental infection in feeding or in other ways, and in this we were usually successful. We consider it necessary to reserve as control animals pigs selected from the same lot used for the experiment, and to keep the control pigs under the same external conditions and in the same locality, but, of course, in separate boxes or pens, with the animals experimented upon. Our early experience in buying pigs brought by rail or boat to the city, and in not being minutely careful to avoid accidental infection, led us soon to realize the importance of these painstaking precautions, tedious and expensive as they often were. We felt obliged to reject not a few experiments in which the control pigs were found affected; but we have records of a large number of experiments in which the control pigs were healthy, the utmost caution was observed, and which we believe will stand the most rigid scrutiny.

Time will not permit on this occasion to give more than a general statement of our results, the details of which we expect to publish later.

We have succeeded, by inoculation of pure cultures of the hog-cholera bacillus, in reproducing experimentally in pigs every lesion of the natural disease, including necrotic buttons in the intestine and in all of the other situations mentioned above in describing the situation of such necroses, pneumonia, hepatic necroses, hyaline thrombosis of renal vessels, ecchymoses, etc.

It is hardly necessary to say that our experimental cases were subjected to careful bacteriological examination, and that in the successful cases the hog-cholera bacilli were demonstrated in pure culture.

Subcutaneous inoculation of swine with cultures of the hog-cholera bacillus usually produces a local inflammation with necrosis and sequestration of the inflamed tissues in which the virulent bacilli may persist for months. The animals nearly always recover. Rarely in our experience this mode of inoculation produces general fatal infection with intestinal lesions, such as are observed after feeding and other modes of inoculation.

Feeding cultures of the hog-cholera bacillus produces with great regularity intestinal diphtheritis and general infection without pneumonia. Usually the animal dies after a few days up to two or three weeks, but it may recover; and such cases of recovery afford opportunity to study the reparative process in the intestine. By simply rubbing the lips of pigs with potato cultures we have produced the disease in fatal form. With or without diphtheritic inflammation of the stomach and small intestine we have usually found in these cases an extensive superficial necrosis and diphtheritic inflammation of the mucous membrane, sometimes also reaching the submucous coat, of the large intestine, most diffuse near the ileo-cæcal valve and occurring in the lower part of the colon in the form of more or less circumscribed patches of necrosis and diphtheritis. Some of these circumscribed necrotic patches bear some resemblance to the buttons; but the regular, typical, round, firm, elevated buttons we have been more successful in reproducing by intra-venous and intra-tracheal inoculations.

Intra-venous inoculations produce usually rapidly fatal forms of infection, sometimes of distinctly hemorrhagic and septicæmic type, usually with at least some intestinal diphtheritis, but occasionally without diphtheritis. We have been so fortunate in a few cases after intra-venous injection of very small doses (0.05 c.c. bouillon culture and less) in keeping the animal alive for a longer time and in finding at autopsy typical buttons in the large intestine.

These cases, together with similar ones, as regards intestinal lesions after intra-tracheal inoculation, have enabled us to study different stages in the formation of these buttons, and we are able to say that at least some of the buttons begin as circumscribed nodular inflammatory masses in the submucosa, with, at an early stage, an overlying intact mucosa.¹ We have evidence also of the possibility

¹ The demonstration by us that the buttons may start by nodular foci of inflammation in the submucosa, and that there may be coagulative necrosis in these submucous nodules at a period before the mucous membrane is necrotic, is a strong argument in opposition to Bang's view, mentioned in a previous foot-note, that these deep necroses are produced by his necrosis bacillus and that only the superficial diphtheritic or croupous inflammation is caused by the hog-cholera bacillus, this latter organism simply preparing the way for the penetration of the necrosis bacillus which he finds to be present now and then in the intestine of healthy pigs. We have found the hog-cholera bacillus in the submucous nodules, and sometimes apparently without admixture with other micro-organisms. It must be admitted, however, that it is difficult to succeed in producing typical buttons by inoculating healthy swine with the hog-cholera bacillus.

That the hog-cholera bacillus is capable of producing extensive necroses cannot be doubted, as the result of experiments on rabbits, mice, guinea-pigs, and on swine proves. If anyone wishes to convince himself as to the power of the hog-cholera bacillus to produce extensive and deep local necroses, let him inoculate the organism into the breast muscle of a pigeon. The foci of hepatic necroses found so regularly in rabbits and mice inoculated with the hog-

of the buttons beginning by necrosis and inflammation of the mucous membrane and secondary involvement of the submucosa. //

Intra-pulmonary inoculation through the chest-wall often produces only circumscribed inflammation and sequestration of a limited area of lung at the point of inoculation, but it may cause diffuse hepatization, with general infection and intestinal lesions.

The most successful reproduction of characteristic pneumonia, associated with typical intestinal lesions, we have obtained by intra-tracheal inoculation of bouillon cultures in moderate doses. By this method we have caused diffuse hepatization of one-third and more of both lungs. The hepatization was variegated, red, gray, white, with areas of coagulation necrosis, with exudation of fibrin and leucocytes, with thrombi in the vessels, and with interstitial exudate; in a word, pneumonia resembling forms occurring in the natural disease. In some of these cases there were no strongyles in the bronchi. The hog-cholera bacilli were present in large number and in pure culture, positively without swine-plague bacilli in the lungs and other internal organs. When, as in some of these cases, there were intestinal buttons, hepatic necroses, hyaline in the kidneys, the reproduction of the natural disease was complete.

We consider, therefore, that the evidence is now complete, more so than in any previous experiments, that the hog-cholera bacillus is the cause of hog cholera in swine. That cases of long-standing hog cholera may terminate fatally at a stage so late that the characteristic bacilli have disappeared cannot be urged in opposition to this conclusion, as we have examples enough of the extinction of pathogenic germs from lesions which they have primarily produced; and as an example particularly pertinent, we cite typhoid fever in its late stage where also death may occur from secondary infection. That many of these fatal cases of hog cholera without hog-cholera bacilli are examples of mixed and secondary infection has already been mentioned. Whenever we find the typical button-like lesions of the intestine which are peculiar to hog-cholera, we consider that the case is or has been one of hog cholera whether or not at the time of autopsy living hog-cholera bacilli can be demonstrated in these lesions or elsewhere in the body.

cholera bacillus may be caused also, although less frequently, by the swine-plague bacillus and by many other bacterial species. Bang's view that the necroses in the pneumonia caused by the swine-plague germ (he does not seem to recognize this lesion as referable to the hog-cholera bacillus) are due also to the necrosis bacillus, we also cannot accept, as necrotic pneumonias can readily be produced by intra-tracheal or intra-pulmonary inoculation of the swine-plague bacillus, and at autopsy only the swine-plague bacilli be present.

Is the hog-cholera bacillus identical with any of the bacteria which have been found in Europe in diseases of swine? The only bacteria which come into question are the bacillus of swine fever or pneumo-enteritis in England, the bacillus of Scandinavian swine pest, and that of the French pneumo-enteritis of swine. There is not the slightest ground for supposing that the actively motile hog-cholera bacillus, with its peculiar reaction in milk cultures, its visible growth on potato, its characteristic effects on animals, has anything to do with the smaller, non-motile Schweine-seuche bacillus growing invisibly or not at all on potato, without distinctive reaction in milk cultures, and possessed of different pathogenic properties on animals.¹ The latter bacillus belongs to the hemorrhagic septicæmic group, a widely distributed group, established under this name by Hueppe, for which we possess very unsatisfactory means of differentiation of its members from each other. The hog-cholera bacillus, in our judgment, should not be ranked with the members of this group.

As was stated for the first time by one of us (Welch), as the result of a comparison of cultures, in an article published in 1889, F. Billings' swine-plague bacillus is identical with the genuine hog-cholera bacillus. Without mention and probably without knowledge of our work, Frosch and other German investigators later came to the same conclusion. Billings' designation of swine-plague bacillus for the hog-cholera bacillus has not gained currency in this country, whereas the name swine-plague bacillus has been introduced by the Bureau of Animal Industry for a totally different species of bacterium belonging to the hemorrhagic septicæmic group. On this occasion we beg to express our thanks to F. Billings for the numerous cultures which he has sent us.

¹ That so many German investigators should have thought it necessary to devote so much time and work to proving over and over again that the hog-cholera bacillus is not identical with the Schweine-seuche bacillus is due to the confusion introduced into this whole subject by the writings of F. Billings. The description of the hog-cholera bacillus in the publications of the Bureau of Animal Industry and in the preliminary report by Welch, in 1889, rendered it impossible to confound the hog-cholera bacillus with the Schweine-seuche bacillus. The organisms which really need comparison are the hog-cholera bacillus and the swine-pest bacillus on the one hand, and the swine-plague bacillus and the Schweine-seuche bacillus on the other hand. It is somewhat remarkable that in an article from Baumgarten's laboratory by Racuglia, entitled "Comparative Experimental Investigations concerning the Bacteria of the German (Löffler-Schütz) Schweine-seuche, the American Swine Plague, and the Danish Swine Pest" (by American swine plague is meant hog cholera), the only bacteria compared by personal experimental work are the Schweine-seuche bacterium and the hog-cholera bacillus, and that no mention is made of personal observations with swine-pest cultures, although such would be expected from the title of the article, and that in the subsequent article in the same volume, by Afanassieff, the only personal observation of the swine-pest bacillus recorded is that it grows, like the hog-cholera bacillus, on potato (Arb. a. d. Gebiete d. path. Anat. herausg. von Baumgarten, Bd. i., 1892). Both of these articles are valuable and careful bacteriological studies.

The anatomical description of the disease swine fever (Klein's pneumo-enteritis), the Scandinavian swine pest, and at least some of the cases of the French pneumo-enteritis of swine, leaves no doubt of the pathological identity of the disease known by these names with the American hog cholera. One of us (Welch) has had the opportunity of examining specimens from cases of English swine fever and Scandinavian swine pest, and has no hesitation in pronouncing these diseases identical, so far as the lesions are concerned, with our hog cholera.

The description originally given by Klein¹ of the bacillus which he then considered to be the cause of the disease in England cannot be made to apply to the hog-cholera bacillus, as his bacillus was said to form spores and to resemble the hay bacillus.

In 1890 Dr. Klein was so kind as to give one of us (Welch) a culture of the bacillus which he had isolated from cases of English swine fever, and which he then regarded as the cause of swine fever. Through the kindness of Professor Brown, Principal of the Royal Veterinary College of London, and of Mr. Banham, of Cambridge, England, one of us (Welch) was permitted to study pathologically and bacteriologically cases of swine fever occurring near Cambridge, England. Professor Klein's culture and the bacillus isolated from the English cases of swine fever proved to be in all respects, including the degree of virulence, identical with our hog-cholera bacillus. A careful comparison of the English cultures with those of our hog-cholera bacillus was made, as regards morphology, cultural behavior, and pathogenic effects, and no difference was found. Klein's present culture of the swine-fever bacillus, therefore, can hardly be the same as that which he originally described as like that of the hay bacillus, but it is the genuine hog-cholera bacillus, which, of course, forms no spores and does not resemble the hay bacillus.

The bacillus originally cultivated by Bang from the Scandinavian swine pest and described by Selander,² and, later, studied by other investigators,³ is doubtless the hog-cholera bacillus, although it would appear to have been observed oftener in an attenuated form than has been our experience with the American hog-cholera bacillus. We

¹ Klein: *Virehow's Archiv*, Bd. xcv., 1884.

² Selander: *Centralbl. f. Bakter.*, 1888, Bd. iii. p. 361. This work was done under Gaffky, in the Reichsgesundheitsamt in Berlin.

³ Jensen: Abstract in Baumgarten's *Jahresbericht*, 1889, p. 177. (Refers to Bang's investigations.) Welch: *Loc. cit.*, 1889. Frosch: *Zeitschrift f. Hygiene*, 1890 Bd. ix.. Caneva: *Centralbl. f. Bakter.*, 1891, Bd. ix. p. 557. Bunzl-Federn: *Ibid.*, 1891, Bd. ix. 787, and *Arch. f. Hygiene*, 1891, Bd. xii. Afanassieff: *op. cit.*, 1892, p. 263. Bang: *Loc. cit.*, 1892-93.

have already expressed our opinion that some error crept into Selander's work with this bacillus in Pasteur's Institute, so that the bacillus which he obtained from his experiments there, and which he supposed to be the swine-pest bacillus of highly exalted virulence, was in reality a different bacterium. We at least feel justified in calling for a repetition by others of these experiments of Selander, with the undoubted swine-pest or hog-cholera bacillus, and for an independent examination of cultures of Selander's Paris bacterium, as well as of Metchnikoff's so-called hog-cholera microbe.

In Selander's original description of the swine-pest bacillus, he speaks of its growing upon potato like the typhoid bacillus. Frosch, who worked with cultures from the same source, was unable to confirm this.¹ As a matter of fact, the appearance of the growth upon potato of the hog-cholera bacillus is somewhat variable, and exceptionally its growth may be scarcely visible or even invisible upon potato, so that we are inclined to the view that Selander did not make a large number of observations of potato cultures of this organism, and happened to observe the exceptional typhoid-like growth. In our preliminary report of 1889 we stated, from personal comparison of cultures, the probable identity of the hog-cholera and swine-pest bacilli.

We were so fortunate as to be supplied again, in 1890, with a culture of the swine-pest bacillus from the Hygienic Institute in Berlin. This was stated to be from the original Bang-Selander stock. Morphologically and in cultures, notably in milk cultures and on potato, we were unable to detect any significant difference between this culture and the hog-cholera cultures. The swine-pest bacillus grew on media somewhat more luxuriantly than the hog-cholera bacillus. Although pathogenic for mice, the swine-pest culture, however, failed to kill rabbits by subcutaneous inoculation, although by intra-venous inoculation it was fatal with the same lesions and distribution of the bacteria as in the case of our hog-cholera bacillus. As we have obtained from hog cholera in this country a bacillus in all respects identical with this swine-pest bacillus, and which we regard as a somewhat attenuated form of the hog-cholera-bacillus, we agree with those who have found the Scandinavian swine-pest bacillus to be identical with our hog-cholera

¹ Loc. cit. It should be noted that according to Jensen's article (already cited), published in 1889, Bang distinctly denies the accuracy of this statement of Selander, and says that his swine-pest bacillus is in all respects identical with Salmon's hog-cholera bacillus. Of the subsequent investigators, only Caneva finds this typhoid-like growth of the swine-pest bacillus.

bacillus. It remains to be determined by larger experience whether the attenuated bacillus is more common in the Scandinavian cases than in the American cases. It would appear from Bang's latest study of the subject, that the bacillus isolated from chronic cases of Scandinavian swine pest is of decidedly attenuated virulence. Bang found his swine-pest bacillus from the epizootic of 1887 identical with our hog-cholera bacillus.

The culture of the swine-pest bacillus brought to the Bureau of Animal Industry in Washington by Lundgren in 1888 was stated to be devoid of virulence for mice, rabbits, and pigs. It is left undecided by Salmon and Smith whether this was an attenuated culture of the hog-cholera bacillus, or, as suggested by Lundgren, some other bacillus brought to this country by mistake for the genuine swine-pest germ.

Frosch (1890) concludes that Selander's swine-pest bacillus is identical with the American hog-cholera bacillus, but the only mention which he makes of inoculation of animals with the former is the statement that it possessed less virulence for guinea-pigs than was found by Selander, and less than the American hog-cholera bacillus. Selander in his original brief communication (1888) found the swine-pest bacillus virulent for mice, rabbits, and guinea-pigs, both by subcutaneous inoculation and by feeding.

Caneva found that the swine-pest bacillus (Selander) was closely allied to the American hog-cholera bacillus (Salmon), but differed from it by typhoid-like growth on potato and by absence of pathogenic effect when inoculated subcutaneously in rabbits. As we have already stated, we, as well as others, found no difference between the potato-growth of swine pest and of hog cholera, and that although the swine-pest culture in our possession was not virulent by subcutaneous inoculation of rabbits, it produced by intra-venous inoculation the same effects as the hog-cholera bacillus, with the same tendency to cause intestinal lesions in rabbits that was noted with our attenuated hog-cholera bacillus more frequently than with the virulent bacillus. The usual extensive necroses in the liver and the occasional formation of hyaline in the renal vessels were produced by this swine-pest germ as well as by the hog-cholera bacillus.

The only statement made by Afanassieff as to his study of the swine-pest bacillus is that it grows on potato like the hog-cholera bacillus. This leads Baumgarten to remark in a foot-note that by this observation of Afanassieff (it had already been made by Bang,

Frosch, and others) it is established that "in all essential points complete agreement exists between these two bacteria."

As we have not had opportunity personally to study cultures from pneumo-enteritis in swine occurring in France, we shall not discuss the results of the bacteriological study of this disease published by French investigators, save to remark that different observers have evidently obtained different bacteria from these cases, and that among these bacteria can probably be recognized, although not with absolute certainty from the descriptions, the swine-plague bacillus and the hog-cholera bacillus. We have already criticised Metchnikoff's so-called hog-cholera microbe, which we do not recognize as the genuine hog-cholera bacillus.

It seems to us clear that we have still to await a much more thorough and extensive bacteriological study of the natural disease which occurs in Europe and is evidently identical with our hog cholera than has yet been furnished us by European investigators with the exception of Bang, before a satisfactory comparison can be made between their results and those obtained in this country on the basis of a much larger experience and more thorough bacteriological work with the natural disease. We trust that such studies will be based upon complete bacteriological examinations of all of the organs of a large number of cases in different epizootics and in different localities, and in the various stages and types of the disease, as has already been done in this country, and that attention will be paid to complicating micro-organisms when present.

We have thus far considered the hog-cholera bacillus and its etiological significance. It remains to say something concerning our experience with the swine-plague bacillus about which there has been so much controversy. This bacillus, as we have repeatedly mentioned, belongs to the group of bacteria which has received from Hueppe the name of the bacteria of hemorrhagic septicæmia. It is a totally different species from the hog-cholera bacillus. Its characters were described by one of us (Welch) in 1889, in essential conformity with those described in the publications of the Bureau of Animal Industry. Two main types, with transitions, of virulence can be distinguished; with one kind rabbits are killed by subcutaneous inoculation in from sixteen to thirty hours, usually with enormous multiplication of the bacilli in the blood and organs; with the other kind rabbits die in from two to six days, occasionally longer, with extensive sero-purulent infiltration around the seat of inoculation, often with peritonitis, and frequently in these cases with few

bacteria in the blood and organs, but an immense number in the inflammatory exudates. Similar variations in virulence occur with other bacteria of this group.

As our observations of the swine-plague bacillus have been either in hogs affected with hog cholera, or in hogs belonging to herds in which hog cholera was prevalent, it became important, as has already been mentioned, to make in every case complete bacteriological examinations, as without such examination one cannot be sure in case only one organism is found that the other has not been overlooked. Such complete examination includes not only the preparation of cover-slip specimens and of plate or roll cultures from all of the organs, but also the inoculation of rabbits or mice with parts of the organs. We can refer to many cases where, if reliance had been placed exclusively upon cultures, or exclusively upon inoculation of animals, we should have failed to detect the presence of the second organism—either the hog-cholera bacillus or the swine plague bacillus. If both the hog-cholera bacillus and the swine-plague bacillus are present in the part examined, and one of these bacteria greatly predominates in number over the other, cultures are likely to lead to the recognition of only the predominant bacillus, as the second organism may not appear in the culture, or, even if it does, its colonies are distinguished sometimes with such difficulty from those of the other that they can readily escape detection. If a rabbit or mouse be inoculated, the animal will die of swine plague, and the coexistence of hog cholera will thus be unrecognized, if the animal experiment be solely relied upon. In the latter case plate cultures, as has already been mentioned, from the seat of inoculation, may reveal the hog-cholera bacillus associated with the swine-plague bacillus. We have already referred to cases in which the swine plague bacillus was present in the lungs, or in the lungs and all of the organs, including the intestine, and still the hog-cholera bacillus was found also in the intestine. The separation of virulent hog-cholera bacilli from the intestine in such cases, with general swine-plague infection, is difficult enough in many cases, but much more difficult is the isolation from the intestine of varieties of the hog-cholera bacillus attenuated in virulence. Indeed, so difficult is this that one can rarely feel sure that it may not have escaped recognition. As has already been mentioned, in prolonged cases of hog cholera the hog-cholera bacilli may have disappeared entirely, so far as the most thorough bacteriological examination can determine; and in some of these cases we have found, with the characteristic intestinal

lesions of hog cholera, pulmonary or even general infection with the swine-plague bacillus. The intestinal lesions, however, were so characteristic of hog cholera that we were not misled into supposing these cases to be primary swine-plague infections.

Of the epizootics studied by us there were more of hog cholera combined with swine plague than of hog cholera without this complication. It is this frequent association of swine-plague infection with hog cholera that has rendered especially difficult the bacteriological study of hog cholera, and the determination of the pathogenic rôle of each of these species of bacteria. It is this association which makes it of first importance to determine by experimental inoculation of swine, and by the examination of uncomplicated cases of each variety of infection, exactly what the hog-cholera bacillus can do and what the swine-plague bacillus can do, alone or in combination with each other.

We have already stated our conclusions as to the pathogenic and etiological rôle of the hog-cholera bacillus. We have proven by experiments, which we believe were conducted with the strictest precautions to guard against error, that the hog-cholera bacillus can produce all of the lesions of the natural disease which we have enumerated, including characteristic extensive pulmonary hepatization and intestinal buttons, lesions which, so far as we can determine, had not before our experiments been satisfactorily reproduced by inoculation of pure cultures under strict precautions to avoid accidental and previous infection; and we consider that the experimental production of the typical button-like lesions was essential in order to establish positively the causative relation of the hog-cholera bacillus to the natural disease—hog cholera. As the workers in the Bureau of Animal Industry deny that the hog-cholera bacillus can produce pneumonia, save possibly some broncho-pneumonia, our demonstration that this bacillus may cause extensive hepatizations, such as are observed in the natural disease, and which they refer apparently always to the swine-plague bacillus, we believe to be also an important addition to our knowledge of the pathogenic effects of this interesting micro-organism.

The class of cases in which we have found most frequently the swine-plague bacillus have been those with pneumonia and fibrinous pleurisy, not very infrequently also fibrinous pericarditis and rarely fibrinous peritonitis. The pneumonia was often very extensive, involving a large part of one or both lungs. The character of the hepatization varied, and was often mixed—gray, reddish-gray, red,

hemorrhagic, white, necrotic. There was sometimes much interstitial œdema or even solid interstitial exudate in the lungs. Coagulative necrosis with nuclear fragmentation occurs. The swine-plague bacilli were often abundant, either alone, or mixed with hog-cholera bacilli, in the hepatized lung and the exudates on serous membranes. The number, distribution and exclusive presence of swine-plague bacilli in these parts in many cases of the natural disease would lead to the probable inference that they were the cause of these inflammatory lesions; nevertheless, of course, such an inference must be confirmed by experiments on swine before it can be accepted as a positive fact. The swine-plague bacilli were sometimes confined to the lungs or to exudates on serous membranes; sometimes they were found also in larger or smaller number in one or more of the following situations: the blood, spleen, kidneys, liver, lymphatic glands, and intestine; in other words, the infection with these bacteria may be either local or general. We were not able, however, to refer to their presence any definite lesions in these latter situations, save possibly in the intestine, a point which, for manifest reasons, we felt required experimental evidence to decide.

We do not consider it necessary to report here our experiments in inoculating rabbits and other laboratory animals.

Our results from inoculation of swine with pure cultures of the swine-plague bacillus are briefly as follows:

There are marked variations in virulence. Some varieties possessed slight or no virulence when tested on swine. Other varieties were markedly virulent. The duration of life in fatal cases varied from sixteen hours to eight or ten days, rarely more. We have not been in possession of any cultures of this bacillus which were generally fatal to swine by subcutaneous inoculation. We have records, however, of a small number of cases in which fatal general infection exceptionally followed this mode of inoculation, there being extensive inflammatory œdema at the site of inoculation. Intra-venous inoculation of very large doses of virulent cultures was generally fatal, of smaller doses was occasionally fatal, often not. By this method of inoculation, even with small doses, we have succeeded in producing multiple serositis (fibrinous pleurisy, pericarditis), both with and without pneumonia. Direct inoculation into serous cavities was sometimes not fatal, although it caused more or less extensive fibrinous inflammation; sometimes it was followed by rapidly fatal general infection with local or multiple serositis. Inoculation directly into the lungs, or better, into the trachea of bouillon cultures

furnished us with a number of examples of exquisite characteristic pneumonia, with necrosis, such as has been described, associated with fibrinous pleurisy, sometimes with pericarditis. Like other methods of inoculation, however, this one was not uniformly fatal, even with virulent cultures. Feeding even enormous quantities of swine-plague cultures, as well as the bodies of animals dead of swine plague, produced no effect; and pigs so fed and killed after varying intervals, presented no definite lesions of the stomach or intestine. Inoculation in two cases directly into the intestine after laparotomy was followed by fatal peritonitis without characteristic lesion of the intestine, some of the culture having evidently entered the peritoneal cavity. Combined inoculations of swine-plague and hog-cholera cultures, or inoculations of swine plague before or after inoculation of hog-cholera cultures did not give satisfactory evidence of increased susceptibility of the swine to one or the other of these organisms. Mixed infections were obtained in this way, resembling mixed natural infection.

In fatal cases of pure experimental swine-plague infection of swine we noted in several, but not in the majority of cases, swelling of the follicles, hyperæmia, diffuse redness, and ecchymoses in the intestinal mucosa, particularly of the large intestine, combined often with catarrhal enteritis. Superficial erosions of the hemorrhagic foci and superficial necrosis of these foci were rarely observed. The swine-plague bacillus may produce a hemorrhagic enteritis, as our experiments show. No extensive intestinal diphtheritis, necrosis, ulceration, and nothing resembling the button-like lesions of hog cholera were observed.

In sequestered sloughs and local inflammatory exudates produced by inoculation of swine-plague bacilli we have found living and virulent swine-plague bacilli as long as two months after the inoculation, the animals having otherwise recovered, and having been killed for the examination. The swine-plague bacilli, therefore, may survive in the animal body longer than in cultures.

The bacteriological examination of pigs dead of experimental swine-plague infection showed the characteristic bacilli pure and in enormous number in the local inflammatory exudates, and in smaller number in other parts, or absent entirely from other parts.

We may conclude, therefore, from these experiments that virulent swine-plague bacilli are capable of causing general infection, and more especially local infections characterized by pneumonia and fibrinous inflammations of serous membranes. This conclusion is in

harmony with the observations of the distribution of this micro-organism and the lesions observed in the natural disease. We find no evidence that the swine-plague bacillus can produce intestinal lesions which are characteristic of hog cholera, although they may cause ecchymoses, hyperæmia, hemorrhagic enteritis, catarrhal inflammation, and probably superficial necroses and erosions. The experimental evidence that they may cause superficial croupous or diphtheritic inflammation of the intestinal mucosa is not conclusive. Notable differences between the hog-cholera bacillus and the swine-plague bacillus are the certainty with which virulent cultures of the former cause intestinal diphtheritis by feeding, and the innocuousness of feeding cultures of the latter to swine, and also the readiness with which pneumonia and fibrinous serositis may be produced by inoculation of the swine-plague bacillus, and the comparative difficulty of producing these lesions with the hog-cholera bacillus.

Theobald Smith considers that natural swine-plague infection is to be regarded as an infectious pneumo-enteritis rather than an infectious pneumonia.¹ The intestinal lesions which he attributes to the action of the swine-plague germ are hyperæmia, hemorrhages, catarrhal inflammation and a peculiar croupous exudation occurring as "circumscribed masses of fibrin easily lifted away from the mucosa, leaving a paler, slightly depressed spot, showing no necrosis of tissue." The last lesion and others which he has described are considered to be different from any produced by the hog-cholera bacillus. So far as we can judge from this description, and particularly from the plate illustrating the lesion, we should not regard this lesion as different from that which may be caused by the hog-cholera bacillus, both experimentally and in the natural disease; and in general we do not consider that Dr. Smith has succeeded in proving or even rendering probable that the swine-plague bacillus produces intestinal lesions of a peculiar character distinguishable from lesions which may occur in hog cholera. In only one instance, published by Theobald Smith, was the experimental inoculation of swine with the swine-plague bacillus followed by an intestinal exudate. This case is described as follows: "In one case, as a result of the peritonitis following an intra-abdominal injection, the walls of the small intestine were swollen, inflamed, and a copious, friable, yellowish exudate had formed on the deeply inflamed mucosa." This would appear to have been a superficial diphtheritis, and is attributed by Dr. Smith to an extension of the peritonitis.

¹ Theobald Smith, *op. cit.*, p. 149.

That there may be superficial intestinal areas of necrosis with slight loss of substance on a hemorrhagic basis after experimental inoculation of the swine-plague culture, we have observed and already noted. The well-known relation of epithelial necrosis of mucous membranes to croupous and diphtheritic exudations, and the variety of agencies which may in this way induce intestinal diphtheritis would render it probable that now and then such superficial diphtheritis may be due to the swine-plague bacillus; but at present the evidence for this is in our judgment inconclusive. The fact that feeding swine-plague cultures is not followed by any damage to the intestine is not conclusive evidence that other methods of penetration of the bacilli may not cause intestinal lesions. We have observed the intestinal lesions above specified not only after inoculation of rabbits, but also after intra-venous, intra-thoracic and intra-tracheal inoculation of swine with swine-plague cultures, although in most of our experimental cases the intestine was not affected.

The lesions, therefore, which we have succeeded in producing in pigs experimentally by inoculation of the swine-plague bacillus are most frequently pneumonia and inflammations of serous membranes, rarely hemorrhagic enteritis associated with these lesions, and still more rarely by subcutaneous inoculation spreading subcutaneous inflammatory oedema with general septicæmia. We are not able, however, to distinguish an intestinal form of swine plague, either as an experimental or natural disease disassociated from the pectoral form, nor have any cases of natural swine plague been observed in this country analogous to the so-called cutaneous Schweine-seuche, although, as already mentioned, we have exceptionally produced this form of the disease experimentally. Of course it cannot be denied that in natural swine-plague lesions may occur which do not appear in the experimental disease, as well as lesions in the experimental not observed in the natural affection.

Usually from one and the same pig the swine-plague bacilli isolated in culture are possessed of essentially the same degree of virulence as tested upon animals; indeed, this is in general true of the swine-plague bacilli cultivated from pigs of the same herd affected with the disease. Nevertheless there are exceptions to this, as we have occasionally cultivated from the organs of the same pig, as well as from different pigs of the same herd, extremely virulent swine-plague bacilli, which uniformly kill rabbits by subcutaneous inoculation of small quantities in sixteen to twenty-four hours and bacilli which are fatal to rabbits only after six or eight days. Of course, as already

mentioned, it is not necessary to suppose that the degree of virulence possessed by the bacilli, either of swine plague or of hog cholera, isolated at autopsy, is necessarily the same degree which the bacilli primarily possessed at the time of invasion of the animal, as we have instances of modification of virulence of bacteria in the animal body, particularly in long-standing disease. When, for example, we find hog-cholera bacilli greatly attenuated in virulence in pigs dead of chronic hog-cholera, it may well be that the bacilli at the onset of the disease were of the usual virulence, and that the attenuation has taken place in the body of the animal. The same is also applicable to swine-plague infection.

What anatomical differences are there in the natural disease between cases of pure hog cholera, that is, cases in which the hog-cholera bacilli are the only pathogenic organisms present, and cases of hog cholera associated with the presence of the swine-plague bacillus? In our experience, which on this point is in conformity with that of the Bureau of Animal Industry, the cases of combined hog-cholera and swine plague infections are characterized especially by extensive pneumonia and pleurisy, sometimes by fibrinous inflammation of other serous membranes, in association with the ordinary intestinal lesions of hog cholera. Fibrinous pleurisy and pericarditis may be present in these cases with little or no pneumonia, but in most cases pulmonary hepatization is a marked feature of the combined infection. From the experimental evidence as to the pathogenic properties of the swine-plague bacillus already adduced, as well as from the bacteriological analysis of these cases, it cannot be doubted that the swine-plague bacillus is a cause of such pneumonias and fibrinous serositis.

In many of the cases of pure hog-cholera without concurrent swine plague infection, pneumonia has been absent or there has been only such broncho-pneumonia as could be referred to bronchial strongyles which are extremely common in the pigs of Maryland. In a certain number of these cases of pure hog cholera, however, we have found pneumonia of a different type and resembling, in its tendency to become necrotic and its variegated aspect, the pneumonia caused by swine-plague bacilli. Usually the pneumonia was less extensive and less likely to be associated with extensive pleurisy than in cases of combined infection, but occasionally it involved large areas of one or both lungs, and there was fibrinous pleurisy. In these cases we found hog-cholera bacilli alone. It may be urged that in these cases the pneumonia was caused by swine-plague bacilli

which had perished. In opposition to this view it may be stated that the swine-plague bacilli may survive at least two months in local exudates in swine as we have shown by experiment, and moreover some of these cases were recent cases, as was shown both by the anatomical and the clinical characters. Again, we have demonstrated experimentally that the hog-cholera bacillus is capable of setting up such pneumonias in swine as those under consideration. For these reasons, therefore, we must differ from the views expressed in the publications of the Bureau of Animal Industry, and admit that the hog-cholera bacilli may cause and do cause pneumonia in swine. We do not wish to be understood as denying that the swine-plague bacilli may die after setting up pneumonia.

In this connection we must again call attention to the cases already mentioned in which we found swine-plague bacilli in hepatized lungs or in the lungs and other internal organs, or in one or more of these situations and in the intestine, and were able to detect hog-cholera bacilli, either virulent or attenuated, only or chiefly in the intestine. We are not aware that cases of this kind have hitherto been described. These were cases of hog cholera with intestinal lesions, most frequently in the form of typical buttons, combined with swine-plague infection. The probable interpretation of these cases is that at an earlier stage of the disease hog-cholera bacilli were present as usual in internal organs, and that in the course of time they disappeared from these organs but remained in the intestine, which is the part generally most intensely affected by this micro-organism. That the hog-cholera bacilli may be found in internal organs, even when not demonstrable in the intestines, has also been mentioned.

It is not a wide step from these cases to those in which the hog-cholera bacilli have disappeared entirely from the body, leaving behind characteristic necrotic lesions. In these latter cases also the swine-plague bacilli may be present in the lungs and other organs, including the intestines, or they may be confined to the lungs. We have notes of several cases in which rabbits inoculated with typical necrotic buttons died of swine plague without hog-cholera bacilli demonstrable in any part of the body, including the intestine; but for reasons already mentioned we have no doubt that these buttons were caused by hog-cholera bacilli, and certainly not by swine-plague bacilli. We have also observed several cases with swine-plague bacilli in the lungs, and the rabbits were unaffected by inoculation of the necrotic buttons from the same case, showing that neither

virulent swine-plague bacilli nor hog-cholera bacilli were present in these buttons at the time of death. All of these were cases of long standing. It is in these chronic cases especially that we have found hog-cholera bacilli of weakened virulence.

We have evidence, therefore, that hogs which have hog cholera may die infected with swine plague, such infection being characterized generally by pneumonia and pleurisy, when hog-cholera bacilli are demonstrable only in the intestine which presented the lesions of hog cholera; also, that hogs which have had hog cholera may die similarly infected without hog-cholera bacilli being demonstrable at the time of death in the intestine or other organs, although their previous presence is signalized by the persistence of intestinal lesions characteristic of hog cholera. We have also observed combined infection with swine plague and hog cholera in which the hog-cholera bacilli were so attenuated in virulence as not to kill susceptible animals by subcutaneous inoculation. Such attenuated bacilli may be in the intestine, and if confined to this situation the difficulty of demonstrating their presence may be so great that they will readily escape recognition.

These facts, which we are the first to demonstrate by bacteriological examination, must be borne in mind in interpreting cases with intestinal lesions in which only swine-plague bacilli can be detected at autopsy. Laborious as is the examination of the intestine for hog-cholera bacilli, in consequence of the mixture of bacteria there present, such examination, nevertheless, must not be neglected in suspicious cases in which the examination of other parts of the body fails to reveal the presence of these bacilli, and, as our experience has shown, a painstaking bacteriological examination of intestinal lesions will often be rewarded.

We feel compelled to say that not a few of the cases reported in the publications of the Bureau of Animal Industry as cases of pure swine-plague infection, but with intestinal lesions sometimes, to say the least, highly suggestive of hog cholera, were not studied bacteriologically in a manner to make sure of the absence of hog-cholera bacilli from the intestine and not always of their absence even from other parts, and are not interpreted in these publications with sufficient reference to the possibilities of localization of hog-cholera bacilli exclusively in the intestine, or of entire disappearance of demonstrable hog-cholera bacilli from the body, although we would not be understood as saying that these possibilities are wholly disregarded.

This criticism applies only to a certain number of their cases.

We have no doubt that some of their cases are examples of swine plague uncomplicated by the co-existence or previous presence of hog cholera in the same animal.

We have no doubt of the occurrence of pure and uncomplicated swine plague as an independent disease, and we have observed several such cases. These cases in our experience were scattered cases in hogs belonging to herds other members of which were affected with hog cholera. The evidence that the cases were pure swine plague lay in the entire absence in some of them of intestinal lesions, in the negative result of the examination of all parts of the body, including the intestine, for hog-cholera bacilli; in the anatomical and clinical evidences that the animals had not previously been affected with hog cholera or other disease; in the presence of the characteristic lesions of swine plague, particularly pneumonia and fibrinous pleurisy, and in the demonstration in pure culture, and in large number, of the swine-plague bacilli in the lesions, and often also in other parts. To assume, under these circumstances, that these pigs were infected or had been infected with hog cholera as well as with swine plague is wholly gratuitous and unsupported by a particle of evidence.

It has not been our fortune to observe an epizootic of pure swine plague. All of our cases, and they have been numerous, have been either combined with hog cholera in the same animal or isolated cases of pure swine plague in herds of swine, some members of which were affected with hog cholera.

A critical study of the reports of the Bureau of Animal Industry on this point shows that their experience has not been widely different from our own, although their interpretation of some of their cases differs from that of similar ones observed by us.

In the various epizootics of swine plague, arranged in eleven groups, studied by Theobald Smith¹ there are unquestionably cases of pure swine-plague infection, but not one of these epizootics can be regarded as free from hog cholera in some of the pigs of the same lot. Thus in the groups numbered II., IV., V., VII., VIII., IX., X., and XI. the hog-cholera bacillus was demonstrated in one or more of the pigs, that from IX. being attenuated in virulence. In Group I. "ulcers or indurations of the mucous membrane" of the intestine are stated to be rare, but that they occurred at all makes it probable that some of the pigs had hog cholera. Cultures were

¹ Op. cit.

made only from the spleen. In only one of the eight cases examined did anything grow, and in this both the colon bacillus and the swine-plague bacillus were found. Group III. need not be considered, as only parts of lungs sent to the Bureau were examined bacteriologically. In Group VI. the intestinal lesions are stated not to have "differed on the whole from those observed in hog cholera." Cultures were made only from the spleen. The hog-cholera bacillus was not found, unless possibly in a non-virulent form. In three of the ten cases examined the swine-plague bacillus was demonstrated in the lungs by inoculation of rabbits. The statement as to the intestinal lesions and the incompleteness of the bacteriological examination make it impossible to regard this as an epizootic of pure swine plague.

We know of no reason why epizootics of swine plague without admixture with hog cholera in at least some of the pigs of the same herd should not occur, but that such epizootics actually do occur in this country remains yet to be demonstrated.

How are we to explain the frequent association of swine-plague infection with hog cholera? The observation made by Theobald Smith, that bacteria closely resembling and probably identical with swine-plague bacteria are frequent inhabitants of the exposed mucous surfaces of healthy swine and other domestic animals, is highly suggestive, and favors the view that the swine-plague bacillus is a secondary invader in many cases of hog cholera, just as in typhoid fever and other primary infections in man we have often enough the secondary invasion of pathogenic bacteria often present on healthy mucous membranes. Such an explanation seems satisfactory for the cases in which hog cholera and swine plague are associated in the same animal, but swine plague may occur in pigs which have no hog cholera. As in the cases of the latter kind thus far observed other pigs in the same herd have hog cholera, one may perhaps suppose either that this hog cholera in other pigs has in some way increased the susceptibility of the exposed pigs, which have not actually contracted the disease, to the swine-plague bacillus, or, more probably, has increased the virulence of the swine-plague bacillus so that it can attack healthy pigs. Assuming some such explanation, simply as an hypothesis without demonstration, it would not be probable that hog cholera is the only agency which could increase this susceptibility or enhance this virulence, but other agencies have not been brought to light in this country.

It remains to consider whether the swine-plague bacillus can be

identified with any of the bacteria observed in swine diseases in Europe.

In a recent interesting and important study of swine pest in Denmark, by Bang, the author finds a bacillus which he calls the "vacuole bacillus," and identifies, doubtless correctly, with the swine-plague bacillus of this country. This bacillus was found frequently in swine pest, and is regarded as the cause of the pneumonia and pleurisy associated with swine pest. By inoculating mice and rabbits with bits of organs of pigs dead of swine pest they usually died from infection with this "vacuole bacillus." Pigs inoculated directly into the lungs died of pneumonia without intestinal lesion. Feeding swine with the cultures was harmless. The conclusion reached by this investigation is that in Denmark, as well as in America, swine pest (hog cholera) is often combined with infection with the swine-plague (vacuole) bacillus. This demonstration by Bang of the essential identity of the Danish epizootics with those of this country as regards the two micro-organisms, about which such bitter contests have been waged, is of signal importance, and a confirmation, in important particulars, of the work of the Bureau of Animal Industry and of our own work on this subject.

As already mentioned, both the swine-plague bacillus and the hog-cholera bacillus appear to have been isolated from cases of pneumo-enteritis of swine (hog cholera) in France, but the French investigators have not come apparently to any clear understanding of the relation of these organisms to the natural disease, and often the descriptions of the bacteria concerned are so conflicting or so imperfect that it is difficult or impossible to identify them.

Since the first recognition and description of the swine-plague bacillus in this country, in 1886, in the third annual report of the Bureau of Animal Industry, the important question as to its relation to other bacteria which had been described has been whether or not our swine-plague bacillus is identical with the German Schweineseuche bacillus. That our hog-cholera bacillus was widely different from the Schweineseuche bacillus was clear enough even then, and this matter would have continued clear enough if the writings of F. Billings had not confused those whose knowledge of one or both of these organisms was derived only from reading about them.

It was assumed in this first publication of the Bureau of Animal Industry that the swine-plague bacillus is identical with the Schweineseuche bacillus, which at that time had been shown by Schütz to be the cause of infectious pneumonia in pigs in Germany. The name

swine plague (which in the previous report of the Bureau of Animal Industry had been given to hog cholera) was transferred to the disease caused by the new bacillus, on the supposition that it was the cause of epizootic disease in this country, identical with the German Schweine-seuche. Some confusion would have been avoided if another name had been selected for the new bacillus.

We were the first to institute a comparison between cultures of the swine-plague bacillus and the Schweine-seuche bacillus. The latter was obtained from the Hygienic Institute in Berlin in the early part of 1889, and as stated in an article published by one of us (Welch) in 1889 the Schweine-seuche bacillus appeared to be identical with the swine-plague bacillus. This statement was based upon a comparison of the cultures and the inoculation of rabbits and mice. We obtained a second culture of the Schweine-seuche bacillus from the Hygienic Institute, through the kindness of Drs. Von Esmarch and R. Pfeiffer, in 1890. This culture was extremely virulent, far more so than the first. It could not be distinguished as regards the morphology of the bacteria, their behavior in culture media, and their pathogenic effects on mice, rabbits and guinea-pigs from cultures of our most virulent swine-plague bacillus, but it differed from the swine-plague cultures in being uniformly fatal to pigs by subcutaneous inoculation in moderate doses. In this respect, as in all others, it was like a culture of the Wild-seuche bacillus which we obtained from Berlin. We have never, out of the large number of swine-plague cultures obtained from various epizootics in this country, found one which was usually fatal to pigs by subcutaneous inoculation, although now and then a pig would die from general infection by this method with lesions identical with those after inoculation with the virulent Schweine-seuche germ, namely, spreading local œdema and general septicæmia. The local œdema, however, was not so extensive as in the Schweine-seuche cases. Still a third culture obtained from Kral, in Prague, was again less virulent and indistinguishable from swine-plague. Whether, as claimed by F. Billings, under the name Schweine-seuche have been embraced different affections, of which one is identical with Wild-seuche or, as we think to be more probable, we are to recognize only one Schweine-seuche bacterium with varying degrees of virulence, is not certain. The Wild-seuche bacterium is now considered by some to be identical with that of Schweine-seuche. The Schweine-seuche cultures, both those fresh from the pig and old ones, in the hands of German investigators have also varied decidedly in virulence, as do also those

of our swine-plague, although no swine-plague culture, even fresh from the pig, has been obtained equalling in virulence, as tested on pigs, the most virulent Schweine-seuche cultures. We observed that pigs which survived repeated inoculation with swine-plague cultures had not lost in any degree their susceptibility to Schweine-seuche. We have had most virulent swine-plague cultures which retained their primary virulence indefinitely in successive cultures.

The only other investigators who have compared, so far as we are aware, cultures of Schweine-seuche and of American swine-plague have been Theobald Smith¹ and Afanassieff.² Smith used the two Berlin cultures of Schweine-seuche which we gave him. With the first culture he did not succeed in killing rabbits, whereas we produced with it, although not uniformly, the same effects in rabbits as with the swine-plague germ of weakened virulence, that is, after subcutaneous inoculation, local exudate at site of inoculation and peritonitis, the rabbits dying in intervals varying from four to fifteen days. The morphological and biological properties of the two bacteria he found identical. His results with the second culture were identical with our own.

Afanassieff, who worked in Baumgarten's laboratory, obtained his culture of the swine-plague bacillus from F. Billings. It was of weak virulence as compared with many cultures of swine plague which in small doses kill rabbits regularly in less than twenty four hours. He comes to the conclusion that this culture is identical with that of Schweine-seuche of weak virulence. He made no comparison by inoculation of pigs, which in our experience it is important should be done.

Our own conclusion as to the bacteria of Schweine-seuche and of swine plague is that no difference exists between them as regards morphology, cultural behavior, and pathogenic effects on rabbits, mice, and other laboratory animals. Cultures of each occur which are also indistinguishable by inoculation of pigs. The only difference by laboratory experiment which has thus far been brought out is that there occur Schweine-seuche bacteria of higher degree of virulence as tested on pigs than any swine-plague bacteria which have hitherto been isolated from pigs in this country. Another point to be considered in this connection is that Schweine-seuche occurs as an independent disease in Germany without association with hog cholera, whereas swine plague has not been shown to

¹ Smith, op. cit.

² Afanassieff, loc. cit.

prevail with the same independence as an epizootic in this country. Nor have any cases of cutaneous swine plague analogous to the so-called cutaneous Schweine-seuche been observed in this country as a natural disease.

These points of difference do not suffice to distinguish the bacillus of Schweine-seuche from that of swine plague; at the same time they indicate that we are not at present warranted in asserting unqualifiedly the absolute identity of these bacteria. The whole question as to identity and to separation into varieties and species of various members of the group of bacteria which includes those of swine-plague, Schweine-seuche, Wild-seuche, rabbit septicæmia, chicken cholera, etc., is a difficult and perplexing one which has not been satisfactorily settled, notwithstanding the large amount of labor devoted to it. In solving the problem we must take into consideration not only laboratory experiments but also the careful study of the natural diseases caused by the bacteria in question.









